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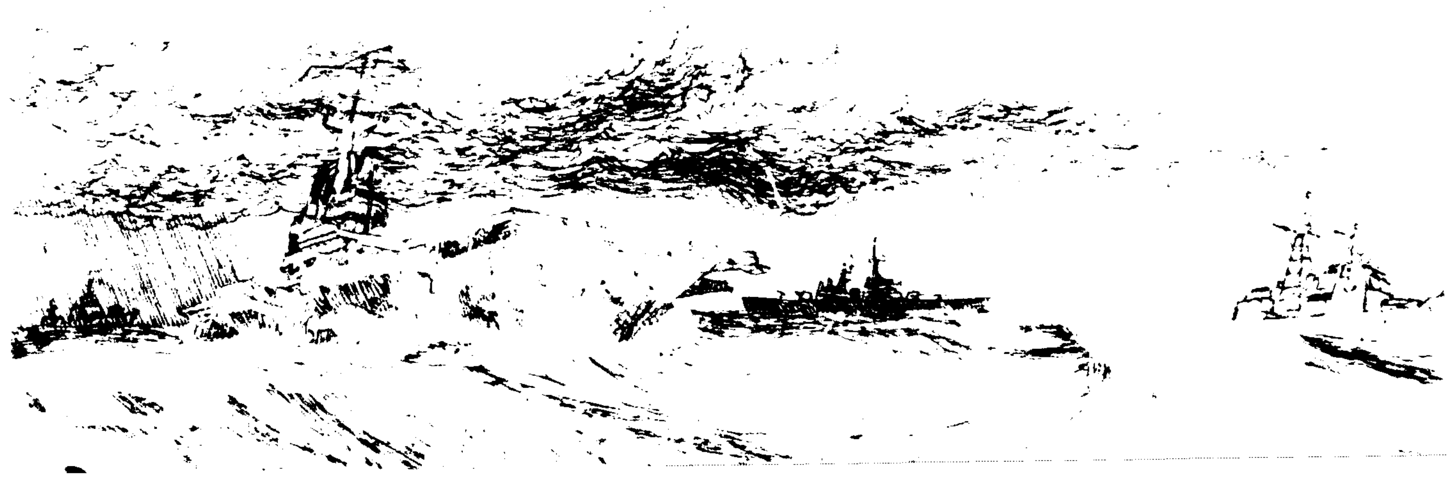
SEVERE WEATHER GUIDE MEDITERRANEAN PORTS

13. MONACO



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This handbook for the port of Monaco, one in a series of severe weather guides for Mediterranean ports, provides decision-making guidance for ship captains whose vessels are threatened by actual or forecast strong winds, high seas, restricted visibility or thunderstorms in the port vicinity. Causes and effects of such hazardous conditions are discussed. Precautionary or evasive actions are suggested for various vessel situations. The handbook is organized in four sections for ready reference: general guidance on handbook content and use; a quick-look captain's summary; a more detailed review of general information on environmental conditions; and an appendix that provides oceanographic information.

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CONTENTS

FOREWORD

This handbook on Mediterranean Ports was developed as part of an ongoing effort at the Naval Environmental Prediction Research Facility to create products for direct application to Fleet operations. The research was conducted in response to Commander Naval Oceanography Command (CNOC) requirements validated by the Chief of Naval Operations (CNO).

As mentioned in the preface, the Mediterranean region is unique in that several areas exist where local winds can cause dangerous operating conditions. This handbook will provide the ship's captain with assistance in making decisions regarding the disposition of his ship when heavy winds and seas are encountered or forecast at various port locations.

Readers are urged to submit comments, suggestions for changes, deletions and/or additions to NOCC, Rota with a copy to the oceanographer, COMSIXTHFLT. They will then be passed on to the Naval Environmental Prediction Research Facility for review and incorporation as appropriate. This document will be a dynamic one, changing and improving as more and better information is obtained.

M. G. SALINAS
Commander, U.S. Navy

PORT INDEX

The following is a tentative prioritized list of Mediterranean Ports to be evaluated during the five-year period 1988-92, with ports grouped by expected year of the port study's publication. This list is subject to change as dictated by circumstances and periodic review.

1988 NO.	PORT
1	GAETA, ITALY
2	NAPLES, ITALY
3	CATANIA, ITALY
4	AUGUSTA BAY, ITALY
5	CAGLIARI, ITALY
6	LA MADDALENA, ITALY
7	MARSEILLE, FRANCE
8	TOULON, FRANCE
9	VILLEFRANCHE, FRANCE
10	MALAGA, SPAIN
11	NICE, FRANCE
12	CANNES, FRANCE
13	MONACO
14	ASHDOD, ISRAEL
15	HAIFA, ISRAEL
	BARCELONA, SPAIN
	PALMA, SPAIN
	IBIZA, SPAIN
	POLLENSA BAY, SPAIN
	VALENCIA, SPAIN
	CARTAGENA, SPAIN
	GENOA, ITALY
	LIVORNO, ITALY
	SAN REMO, ITALY
	LA SPEZIA, ITALY
	VENICE, ITALY
	TRIESTE, ITALY

1989	PORT
	SPLIT, YUGOSLAVIA
	DUBROVNIK, YUGOSLAVIA
	TARANTO, ITALY
	PALERMO, ITALY
	MESSINA, ITALY
	TAORMINA, ITALY
	PORTO TORRES, ITALY

1990	PORT
	BENIDORM, SPAIN
	ROTA, SPAIN
	TANGIER, MOROCCO
	PORT SAID, EGYPT
	ALEXANDRIA, EGYPT
	ALGIERS, ALGERIA
	TUNIS, TUNISIA
	GULF HAMMAMET, TUNISIA
	GULF OF GABES, TUNISIA
	SOUDA BAY, CRETE

1991	PORT
	PIRAEUS, GREECE
	KALAMATA, GREECE
	THESSALONIKI, GREECE
	CORFU, GREECE
	KITHIRA, GREECE
	VALETTA, MALTA
	LARNACA, CYPRUS

1992	PORT
	ANTALYA, TURKEY
	ISKENDERUN, TURKEY
	IZMIR, TURKEY
	ISTANBUL, TURKEY
	GOLCUK, TURKEY
	GULF OF SOLLUM

PREFACE

Environmental phenomena such as strong winds, high waves, restrictions to visibility and thunderstorms can be hazardous to critical Fleet operations. The cause and effect of several of these phenomena are unique to the Mediterranean region and some prior knowledge of their characteristics would be helpful to ship's captains. The intent of this publication is to provide guidance to the captains for assistance in decision making.

The Mediterranean Sea region is an area where complicated topographical features influence weather patterns. Katabatic winds will flow through restricted mountain gaps or valleys and, as a result of the venturi effect, strengthen to storm intensity in a short period of time. As these winds exit and flow over port regions and coastal areas, anchored ships with large 'sail areas' may be blown aground. Also, hazardous sea state conditions are created, posing a danger for small boats ferrying personnel to and from port. At the same time, adjacent areas may be relatively calm. A glance at current weather charts may not always reveal the causes for these local effects which vary drastically from point to point.

Because of the irregular coast line and numerous islands in the Mediterranean, swell can be refracted around such barriers and come from directions which vary greatly with the wind. Anchored ships may experience winds and seas from one direction and swell from a different direction. These conditions can be extremely hazardous for tendered vessels. Moderate to heavy swell may also propagate outward in advance of a storm resulting in uncomfortable and sometimes dangerous conditions, especially during tending, refueling and boating operations.

This handbook addresses the various weather conditions, their local cause and effect and suggests some evasive action to be taken if necessary. Most of the major ports in the Mediterranean will be covered in the handbook. A priority list, established by the Sixth Fleet, exists for the port studies conducted and this list will be followed as closely as possible in terms of scheduling publications.

RECORD OF CHANGES

CHANGE NUMBER	DATE OF CHANGE	DATE ENTERED	PAGE NUMBER	ENTERED BY

1. GENERAL GUIDANCE

1.1 DESIGN

This handbook is designed to provide ship captains with a ready reference on hazardous weather and wave conditions in selected Mediterranean harbors. Section 2, the captain's summary, is an abbreviated version of section 3, the general information section intended for staff planners and meteorologists. Once section 3 has been read, it is not necessary to read section 2.

1.1.1 Objectives

The basic objective is to provide ship captains with a concise reference of hazards to ship activities that are caused by environmental conditions in various Mediterranean harbors, and to offer suggestions for precautionary and/or evasive actions. A secondary objective is to provide adequate background information on such hazards so that operational forecasters, or other interested parties, can quickly gain the local knowledge that is necessary to ensure high quality forecasts.

1.1.2 Approach

Information on harbor conditions and hazards was accumulated in the following manner:

A. A literature search for reference material was performed.

B. Cruise reports were reviewed.

C. Navy personnel with current or previous area experience were interviewed.

D. A preliminary report was developed which

E. Port/harbor visits were made by NEPRF personnel; considerable information was obtained through interviews with local pilots, tug masters, etc; and local reference material was obtained (See section 3 references).

F. The cumulative information was reviewed, combined, and condensed for harbor studies.

1.1.3 Organization

The Handbook contains two sections for each harbor. The first section summarizes harbor conditions and is intended for use as a quick reference by ship captains, navigators, inport/at sea OOD's, and other interested personnel. This section contains:

A. a brief narrative summary of environmental hazards,

B. a table display of vessel location/situation, potential environmental hazard, effect-precautionary/evasion actions, and advance indicators of potential environmental hazards,

C. local wind wave conditions, and

D. tables depicting the wave conditions resulting from propagation of deep water swell into the harbor.

The swell propagation information includes percent occurrence, average duration, and the period of maximum wave energy within height ranges of greater than 3.3 feet and greater than 6.6 feet. The details on the generation of sea and swell information are provided in Appendix A.

The second section contains additional details and background information on seasonal hazardous conditions.

1.2. CONTENTS OF SPECIFIC HARBOR STUDIES

This handbook specifically addresses potential wind and wave related hazards to ships operating in various Mediterranean ports utilized by the U.S. Navy. It does not contain general purpose climatology and/or comprehensive forecast rules for weather conditions of a more benign nature.

The contents are intended for use in both pre-visit planning and in situ problem solving by either mariners or environmentalists. Potential hazards related to both weather and waves are addressed. The oceanographic information includes some rather unique information relating to deep water swell propagating into harbor shallow water areas.

Emphasis is placed on the hazards related to wind, wind waves, and the propagation of deep water swell into the harbor areas. Various vessel locations/situations are considered, including moored, nesting, anchored, arriving/departing, and small boat operations. The potential problems and suggested precautionary/evasive actions for various combinations of environmental threats and vessel location/situation are provided. Local indicators of environmental hazards and possible evasion techniques are summarized for various scenarios.

CAUTIONARY NOTE: In September 1985 Hurricane Gloria raked the Norfolk, VA area while several US Navy ships were anchored on the muddy bottom of Chesapeake Bay. One important fact was revealed during this incident: Most all ships frigate size and larger dragged anchor, some more than others, in winds of over 50 knots. As winds and waves increased, ships 'fell into' the wave troughs, BROADSIDE TO THE WIND and become difficult or impossible to control.

This was a rare instance in which several ships of recent design were exposed to the same storm and much effort was put into the documentation of lessons learned. Chief among these was the suggestion to evade at sea rather than remain anchored at port whenever winds of

2. CAPTAIN'S SUMMARY

The Principality of Monaco is located on the southern coast of France in the region known as the French Riviera (Figure 2-1). Monaco, an independent state, is situated approximately 5 mi (8 km) west of the border between France and Italy.

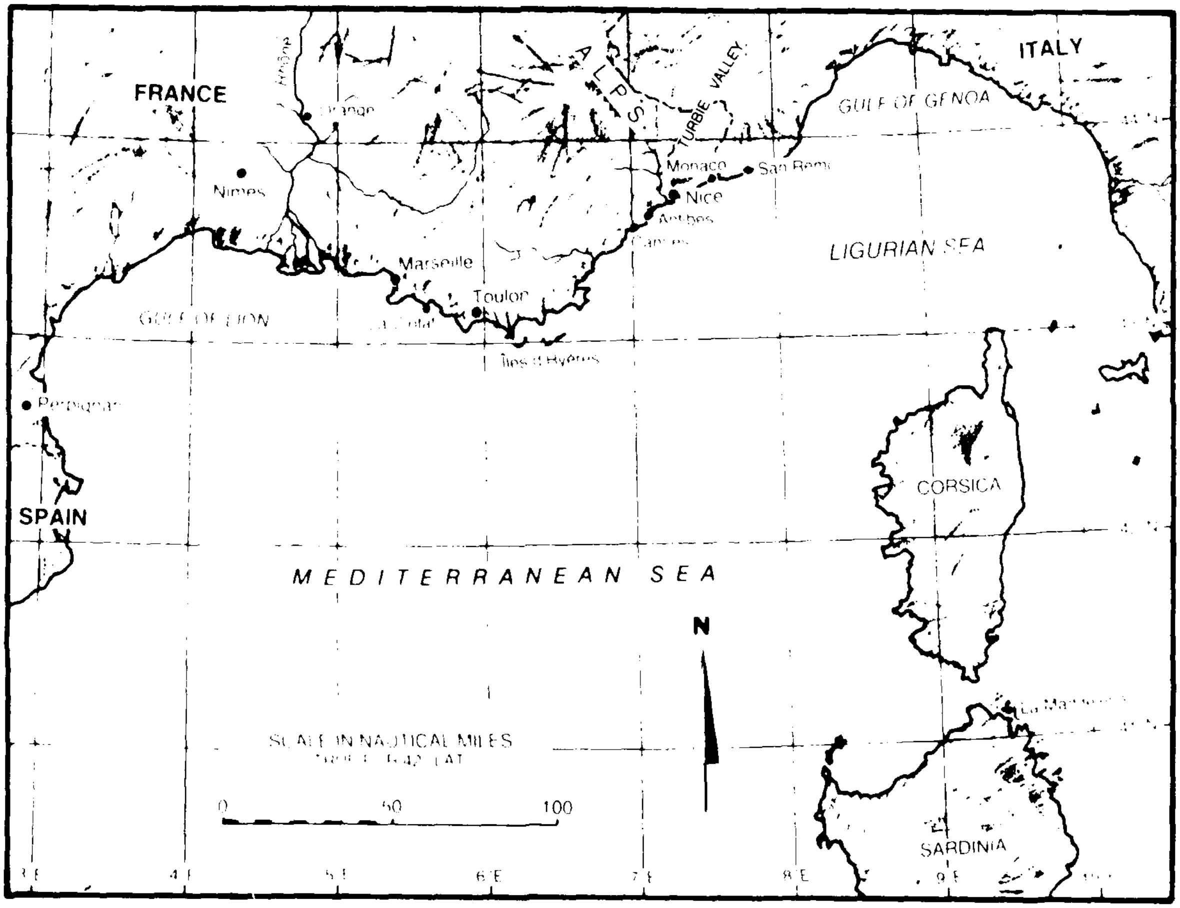

Figure 2-1. The Northwestern Mediterranean Sea.

The harbor facilities at the Port of Monaco are situated between Cap d'Ail, about 1 n mi southwest, and Point of la Veille, about 1 n mi northeast (Figure 2-2).

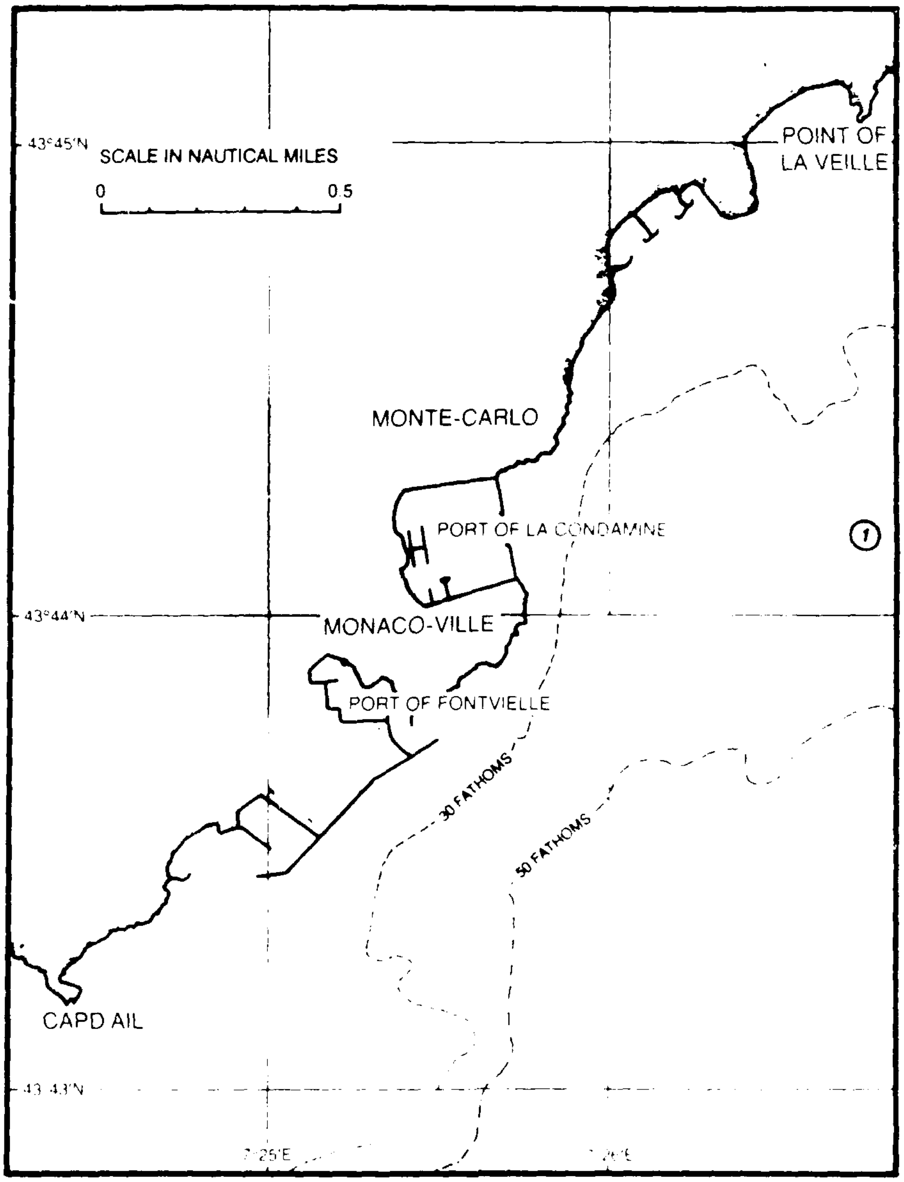

Figure 2-2. Approaches to the Port of Monaco.

The Port of La Condamine is the primary and largest harbor at Monaco. Roughly square in shape with each side approximately 437 yd (400 m) long, the harbor can accommodate vessels to 459 ft (140 m) with drafts of 26 ft (8 m) or less. The 328 ft (100 m) wide harbor entrance is open to the east, and is defined between the ends of two breakwaters: Jetée Nord (north jetty) and Jetée Sud (south jetty). See Figure 2-3. The entrance is approximately 66 ft (20 m) narrower on the bottom than it is at the surface (Hydrographer of the Navy, 1965).

A second harbor, the Port of Fontvielle, is located approximately 765 yd (700 m) southwest of the Port of La Condamine. Significantly smaller, the Port of Fontvielle is satisfactory for use by liberty boats from large ships such as aircraft carriers (FICEURLANT, 1983).

The anchorage is located 0.5 to 1 n mi east of the Port of La Condamine in depths of 30 to 50 fm (55 to 91 m). The holding quality of the steeply sloping sand bottom is unspecified.

The anchorage is exposed, and is most vulnerable, to winds and waves from east clockwise to southwest. Easterly winds during winter commonly attain force 7 or 8 (28 to 40 kt) and may be accompanied by waves of 10 to 13 ft (3 to 4 m). Mistral winds (northeast to north) can reach 40 kt and be accompanied by southwesterly swell waves to 6 ft (2 m). Wind and wind waves are typically from different direction than the swell during Mistral conditions.

Submarine tending at Monaco was tried, but the effort was abandoned because of the southerly swell which, when only 2 ft, would wash over the submarine hulls. Higher southerly swell entering the harbor is not uncommon.

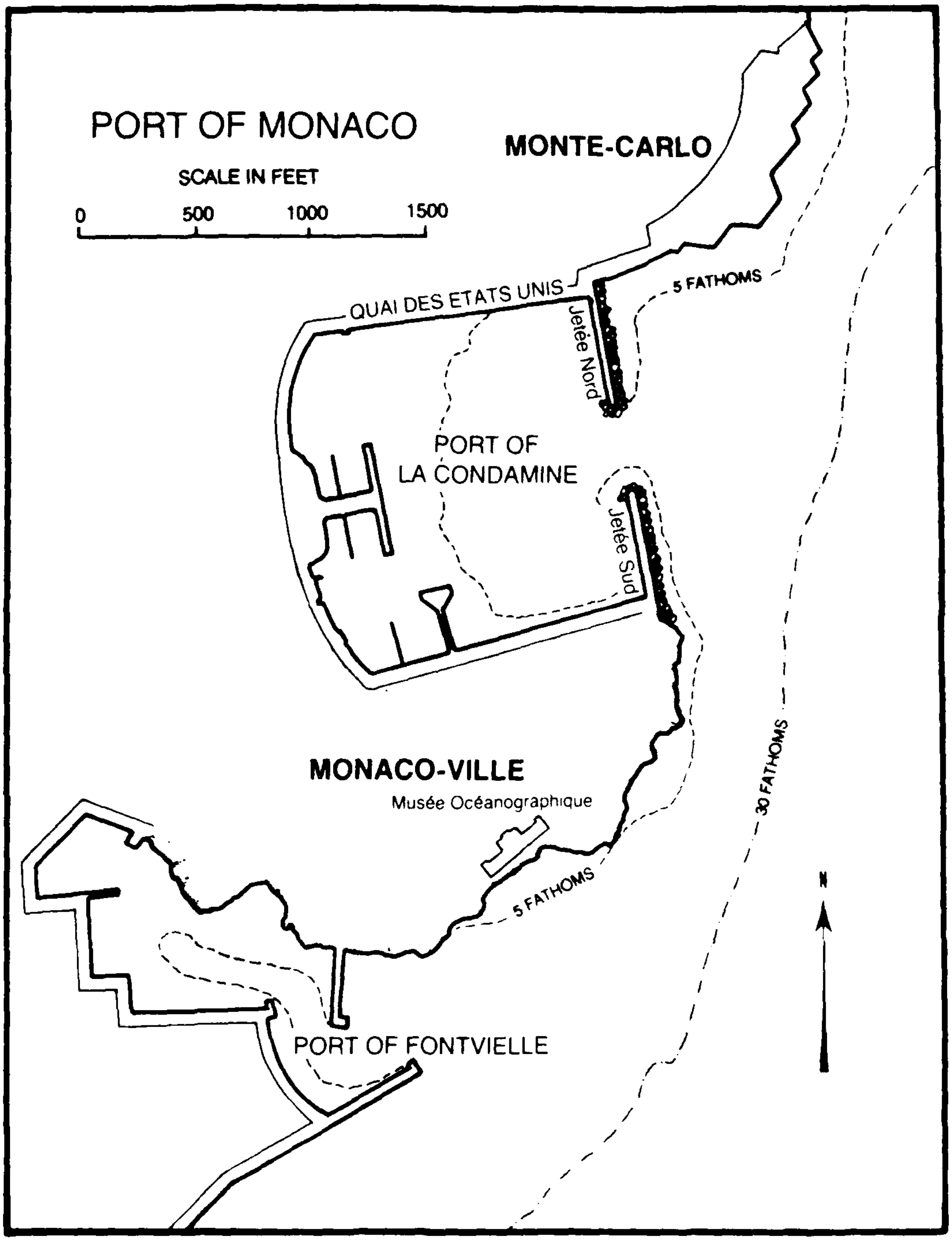

Figure 3-3. Port of Monaco.

No currents are evident at Monaco. Tidal range is slight, only about 8 in (20 cm), and is largely due to barometric pressure changes rather than astronomical influences.

Specific hazardous environmental conditions, vessel situations, and suggested precautionary/evasive action scenarios for the Port of Monaco are summarized in Table 2-1.

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Table 2-1. Summary of hazardous environment

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD

1. <u>E-SE'ly winds/waves</u> - Worst weather condition at Monaco.
* Roadstead is exposed.
* Waves enter inner harbor.
* Strongest in winter, weakest in summer.
* E-SE wind direction occurs 80% of time at Monaco.
* May be accompanied by cloudy, rainy weather.
	<u>Advance warning</u>
	* A falling barometer is a good indication of forthcoming E-SE'ly winds.
	* Any indication of cyclogenesis in the Gulf of Genoa, such as:
	  * When a lee trough in the Gulf of Genoa is overtaken by a cold or occluded front.
	  * The appearance of cold air from the NE in the Po Valley.
	  * The onset of a Mistral in the Gulf of Lion.
	* Strong or strengthening high pressure cell over central Europe with low pressure south or southwest of Monaco.
	
	<u>Duration</u>
	* Wind will likely persist as long as a depression is in the Gulf of Genoa.

2. <u>S-SW'ly winds/waves</u> - Occurs only infrequently. * Most often seen in winter and early spring. * May result in swell to 10 ft (3 m) in coastal waters. * Wind and swell directions may differ.	<u>Advance warning</u> * The early stages of cyclogenesis south of the Alps commonly result in SW'ly 30-40 kt winds in the region between the French coast and Corsica. * Easterly moving depressions moving into the Ligurian Sea or across Corsica into Italy. <u>Duration</u> * Swell may persist for 2-3 days.

onmental conditions for the Port of Monaco

ZARD	VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS

tion of
e Gulf
of
r
	(1) Anchored.	(a) Wind and waves impact the anchorage with full open ocean force.
		* Moderate event may require deployment of 2 anchors.
		* Strong event may dictate moving to a more protected anchorage.
		  * Villefranche offers better protection.
		  * Anchorage no. 1 at Cannes offers better protection.
		(b) Be aware of wind chill factor.

m the
Gulf
cell
south
	(2) Moored - inner harbor.	(a) Waves pass through entrance to Port of La Condamine, and create dangerous conditions in the inner harbor.
		* Sortie from Monaco should be considered.
		  * Anchorage at Villefranche offers better protection.
		  * Anchorage no. 1 at Cannes offers better protection.
		* Quai des Etats Unis is left vacant during winter due to the effects of winds and waves.
		(b) Be aware of wind chill factor.

	(3) Arriving/departing.	(a) Winds and waves impact the anchorage directly and pass through the entrance of the Port of La Condamine.
		* Inbound units should divert to a more protected port.
		  * Anchorage at Villefranche offers better protection.
		  * Anchorage no. 1 at Cannes offers better protection.
		* Outbound units should depart the Port before the onset of the strongest winds and highest waves.
		(b) Be aware of wind chill factor.

	(4) Small boats.	(a) Small boat operation may become hazardous/impossible in a strong event. * Conditions in the inner harbor and the anchorage may preclude safe boat operation. (b) Be aware of wind chill factor.
n of 40 kt n coast to the taly.	(1) Anchored.	(a) A strong event may expose vessels to heavy weather conditions. * Deployment of 2 anchors may be required. * Possibility of wind and swell from different directions makes anchored vessels liable to rolling. * Moving to a more protected anchorage should be considered. * Anchorage no. 2 north of Ile Ste. Marguerite at Cannes offers better protection.
	(2) Arriving/departing.	(a) A strong event may create hazardous conditions for incoming and outgoing vessels. * Deployment of 2 anchors may be required. * Anchored vessels are liable to rolling induced by different wind and swell directions. * Delaying arrivals until after conditions abate is advisable.
	(3) Small boats.	(a) Wind and/or swell outside harbor entrance may create hazardous small boat operating conditions. * Inner harbor operations largely unaffected.

Table 2-

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD
3. Mistral winds/waves - minor impact on Port of Monaco. * Occurs only 3 to 4 times per year at Monaco. * Wind direction is NW to N as wind flows south through Turbie Valley to Monaco. * Wind force is significantly less than that experienced farther west. * Monaco is near the eastern limit of area affected by Mistral wind. * Swell generated by Mistral winds farther west reach Monaco as SW'ly to 6 ft (2 m).	Advance Warning * Once the Mistral has onset farther west, Mistral winds will spread east to Nice and possibly to Monaco if a 10 mb pressure difference exists between Toulon and Nice. * Mistral will start in the Marseille/Toulon area when the following pressure differences are achieved: * Perpignan - Marseille, 3 mb. * Marseille - Nice, 3 mb. * Perpignan - Nice, 6 mb. * Conditions favorable for Genoa low formation are conducive to the start of a Mistral at Marseille. * For Mistral winds to affect the Monaco area, they will first be observed at Marseille/Toulon.

Table 2-1. (Continued)

HAZARD	VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS
	(1) Anchored.	(a) Vessels in anchorage should experience only minor problems. * Two anchors may be required if wind is strong. * Moving to anchorage no. 3 east of Pointe de la Croisette at Cannes should be considered. (b) Be aware of wind chill factor.
	(2) Moored - inner harbor.	(a) Inner harbor should be only minimally affected. (b) Be aware of wind chill factor.
	(3) Arriving/departing.	(a) Conditions nearshore may differ markedly from those existing only 2-3 n mi offshore, where stronger winds may exist. (b) Vessels at Monaco should experience only minor problems. * Two anchors may be required if wind is strong. * Diverting to anchorage no. 3 east of Pointe de la Croisette at Cannes should be considered due to better protection provided. (c) Be aware of wind chill factor.
	(4) Small boats.	(a) Inner harbor operations are largely unaffected. * Wind/wave conditions outside harbor entrance may preclude small boat operations to/from the roadstead until conditions abate. (b) Be aware of wind chill factor.

SEASONAL SUMMARY OF HAZARDOUS WEATHER CONDITIONS

WINTER (November thru February):

* Easterly winds occur 80% of the time with 35-40 kt common.
* Easterly waves can enter the harbor area.
* Mistral, although rare, occur in late winter/early spring.
* Infrequent southerlies can bring 5-6 ft (2 m) waves with maximum heights near 10 ft to anchorage area.

SPRING (March thru May):

* Easterlies still occur but less intense and less frequent.
* Mistral events further west generate swell reaching the Monaco anchorage at heights of 6 ft (2 m).
* Mistral events become rare by late in season.

SUMMER (June thru September):

* Daily sea breeze is rule, usually 10 kt but can reach 25 kt on rare occasions.

AUTUMN (October):

* Short transition season as winter-like weather returns by the end of the month.

NOTE: For more detailed information on hazardous weather conditions see previous Summary Table in this section and Hazardous Weather Summary in Section 3.

REFERENCES

Hydrographer of the Navy, 1965: Mediterranean Pilot, Volume II. Published by the Hydrographer of the Navy, London, England.

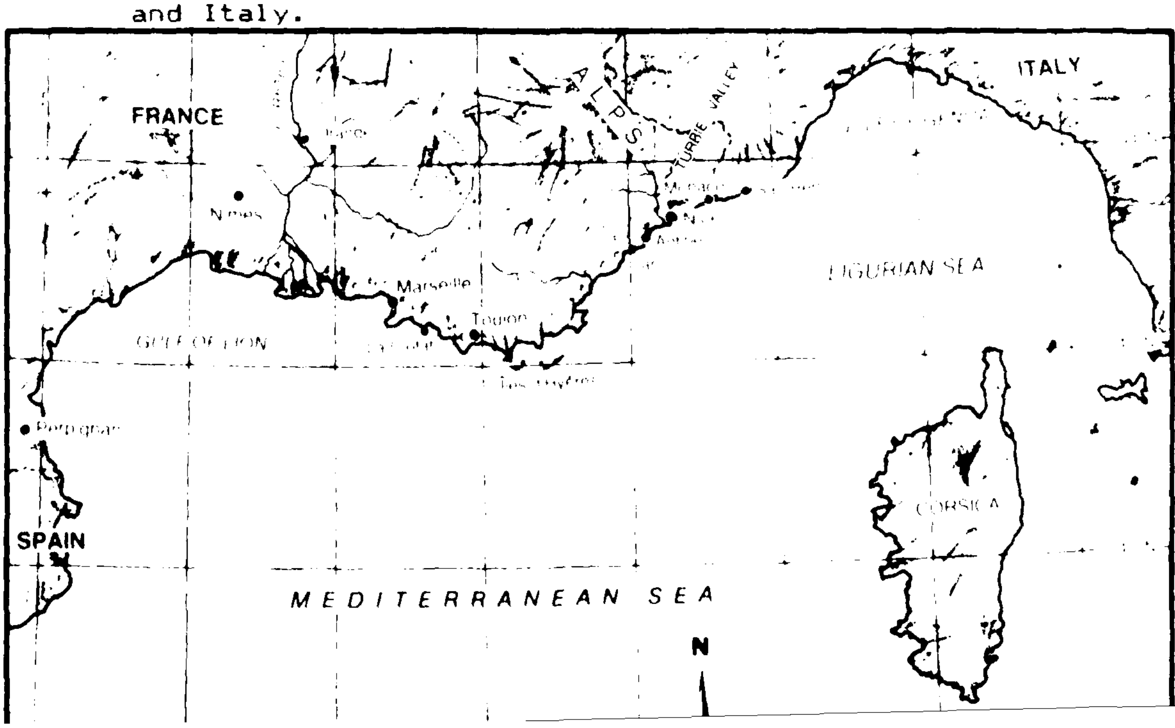
FICEURLANT, 1983: Port Directory. Fleet Intelligence Center Europe and Atlantic, Norfolk, VA.

3. GENERAL INFORMATION

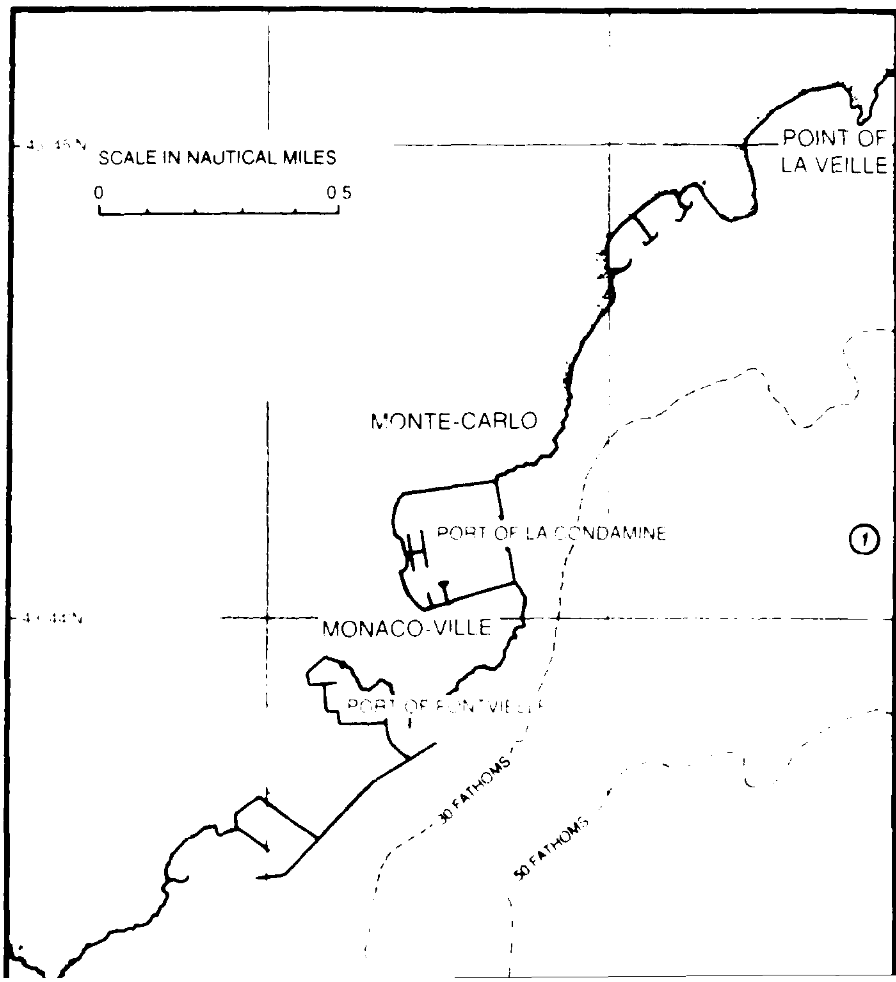
This section is intended for Fleet meteorologists/oceanographers and staff planners. Paragraph 3.5 provides a general discussion of hazards and Table 3-2 provides a summary of vessel locations/situations, potential hazards, effects-precautionary/evasive actions, and advance indicators and other information about the potential hazards by season.

3.1 Geographic Location

The Principality of Monaco is located on the southern coast of France in the region known as the French Riviera (Figure 3-1). Monaco, an independent state, is situated approximately 11 mi (18 km) east of Nice and 5 mi (8 km) west of the border between France and Italy.



The harbor facilities of the Port of Monaco are situated between Cap d'Ail, about 1 n mi southwest, and Point of la Veille, about 1 n mi northeast (Figure 3-2). Monaco may be identified from the surrounding terrain by its numerous buildings, which makes it appear as a white patch on the coast when viewed from a distance to seaward. Prominent landmarks include Rocher de Monaco, a promontory on which Monaco is built, and Musée Océanographique, a large white building which overlooks the sea (Hydrographer of the Navy, 1965). High mountains back the coastline north of Monaco.



The Port of La Condamine is the primary and largest harbor at Monaco. Roughly square in shape with each side about 437 yd (400 m) long, the harbor can accommodate vessels to 459 ft (140 m) with drafts of 26 ft (8 m) or less. The 328 ft (100 m) wide harbor entrance is open to the east, and is defined between the ends of two breakwaters: Jetée Nord (north jetty), and Jetée Sud (south jetty). See Figure 3-3. The entrance is approximately 66 ft (20 m) narrower on the bottom than it is at the surface (Hydrographer of the Navy, 1965).

A second harbor, the Port of Fontvielle, is located approximately 765 yd (700 m) southwest of the Port of La Condamine. Significantly smaller, the Port of Fontvielle is satisfactory for use by liberty boats from ships as large as aircraft carriers (FICEURLANT, 1983).

The anchorage is located 0.5 to 1 n mi east of the Port of La Condamine in depths of 30 to 50 fm (55 to 91 m). The holding quality of the steeply sloped sand bottom is unspecified.

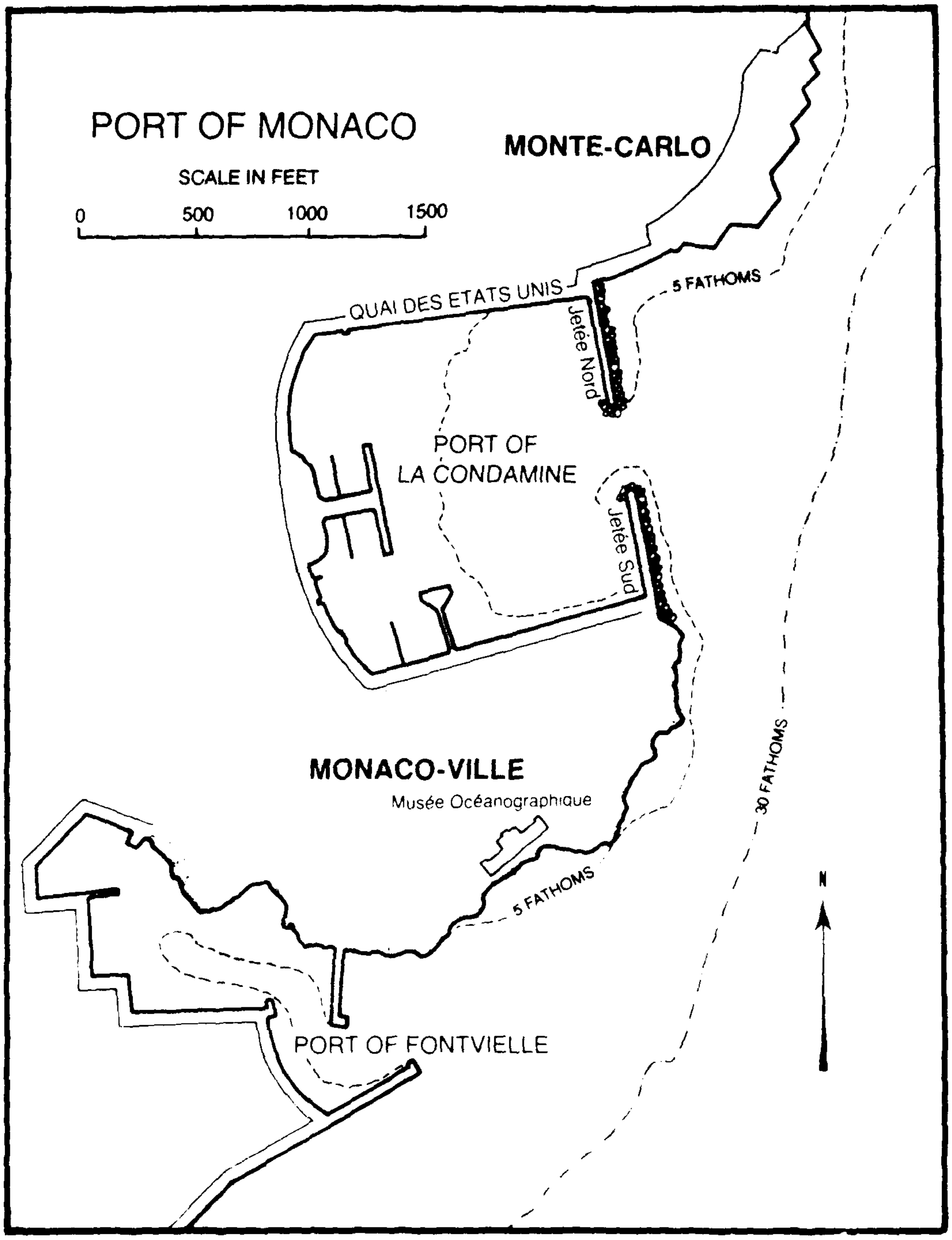


Figure 2-3. Port of Monaco.

3.2 Qualitative Evaluation of the Port of Monaco

The Port of La Condamine is protected naturally by the adjacent landmass from winds and waves from southwest clockwise through north. The two protective breakwaters, Jetée Nord and Jetée Sud, afford only limited protection from the east. Consequently, the harbor is not safe during strong easterly winds. Because of the dangerous wave action, Quai des Etats Unis--the quay along the north side of the harbor--is left vacant during the winter months. Even during the summer months easterly winds can bring problem waves to the harbor, with swell to 5 ft (1.5 m) occasionally passing through the harbor entrance. They tend to reflect off of the face of the quay along the west side of the harbor and cause difficulty for small boats moored nearby. U.S. Navy ships do not commonly enter the inner harbor during any season, preferring instead to anchor in the roadstead.

The boat landing at the Port of Fontvielle is afforded somewhat better protection from easterly wave action by a mole that prevents wave energy from directly entering the harbor.

The anchorage is exposed, and is most vulnerable, to winds and waves from east clockwise to southwest. Easterly winds during winter commonly attain force 7 or 8 (28 to 40 kt) and may be accompanied by waves of 10 to 13 ft (3 to 4 m). Mistral winds (northeast to north) can reach 40 kt and be accompanied by southwesterly swell waves to 6 ft (2 m). Wind and wind waves are typically from different direction than the swell during Mistral conditions.

Submarine tending at Monaco was tried, but the effort was abandoned because of the southerly swell which, when only 2 ft, would wash over the submarine hulls. Higher southerly swell entering the harbor is not uncommon.

3.3 Currents and Tides

No currents are evident at Monaco. Tidal range is slight, only about 8 in (20 cm), and is largely due to barometric pressure changes rather than astronomical influences.

3.4 Visibility

Visibility at Monaco is generally good; fog is not a problem. Visibility is best during a Mistral. It is during Mistral events that the Island of Corsica, about 95 n mi distant, can occasionally be seen.

3.5 Hazardous Conditions

The harbor of the Port of La Condamine and the roadstead are each vulnerable to specific wind and wave conditions. Easterly winds caused by low pressure systems in the Gulf of Genoa (i.e. Genoa lows) cause the greatest problems, but other synoptic events can cause difficulties as well. Because Monaco is located near the eastern limit of the area affected by Mistral winds, the effect of the Mistral is minimized.

Although rare, storms having tropical cyclone characteristics with fully developed eyes have been observed on at least three occasions in the Mediterranean Basin: 23-26 September 1969, 22-28 January 1982, and 26-30 September 1983. On the latter occasion the storm moved northwest from the Gulf of Gabes (on the southeast coast of Tunisia), through the Straits of Sicily, along the east coast of Sardinia, and into the Gulf of Genoa. Winds of 100 kt were observed near the eye while Cagliari, Sardinia reported winds of 60 kt. While the probability of such a storm striking Monaco is very slight, the meteorologist must be aware of the possibility.

A seasonal summary of various known environmental hazards that may be encountered in the Port of Monaco follows.

A. Winter (November through February)

Unsettled weather conditions predominate during winter, largely due to the proximity of Monaco to the Gulf of Genoa. Easterly winds occur approximately 80% of the time, with force 7 to 8 (28-33 kt to 34-40 kt) common.

Monaco is located only about 16 n mi west of San Remo, Italy, the approximate eastern limit of the area affected by Mistral winds. Consequently, the strength and frequency of the Mistral at Monaco is reduced when compared to ports farther west. Nevertheless, Mistral winds can be expected at Monaco 3 or 4 times per year, most often occurring in late winter and early spring in conjunction with a strong Mistral (force 7 to 9 (28-33 kt to 41-47 kt)) over the Gulf of Lion. Mistral winds reach Monaco as north or northwesterly as they funnel southward through the Turbie Valley north of Monaco. Because the winds have an offshore component, they do not raise high waves at Monaco. Mistral winds farther west, however, do raise a swell which reaches Monaco from the southwest with a 6 ft (2 m) height.

Winds with an easterly component--the most prevalent type at Monaco--cause the greatest difficulty at the Port. Commonly accompanied by inclement weather, the wind raises waves which enter the inner harbor. Usually caused by cyclogenesis or an existing depression in the Gulf of Genoa, the easterly winds in winter average force 7 to 8 (28-33 kt to 34-40 kt), with stronger winds occasionally occurring. Swell heights at the anchorage may reach 10 to 13 ft (3 to 4 m). Easterly winds can also be caused by high pressure over central Europe and/or low pressure south or southwest of Monaco. Cloudy, rainy weather would be expected during such an

As is the case for other ports along the French Riviera, southerly winds and waves are rare. They are usually caused by depressions moving into the Ligurian Sea or across Corsica into Italy. The swell is more of a problem than the wind at the anchorage, but should seldom exceed 6 ft (2 m) with maximum heights of 10 ft (3 m). The swell may persist for 2 or 3 days, and arrive or persist after the wind changes direction. The result is a swell direction which is at an angle of 45° to 90° to the wind direction. Because the anchored vessels will head into the wind, the vessels tend to roll (Shaver, undated).

While specific precipitation data for Monaco are unavailable, Biel (1946) states that precipitation can be expected on about 22 percent of the days in January along the south coast of France and the Italian Riviera. Based on Biel's statistic and other local information, it is reasonable to expect some form of precipitation to occur at Monaco on about 6 to 8 days of each winter month, with the lesser frequencies occurring in January and February.

Winter temperatures at Monaco are moderate, with freezing conditions uncommon. Wind chill can be a significant factor, however, for personnel working in exposed locations when the easterly winds begin to strengthen or the Mistral is blowing. Table 3-1 can be used to determine wind chill for various temperature and wind combinations.

Table 3-1. Wind Chill. The cooling power of the wind expressed as "Equivalent Chill Temperature" (adapted from Kotsch, 1983).

Wind Speed		Cooling Power of Wind expressed as "Equivalent Chill Temperature"								
Knots	MPH	Temperature (°F)								
Calm	Calm	40	35	30	25	20	15	10	5	0
		Equivalent Chill Temperature								
3-6	5	35	30	25	20	15	10	5	0	-5
7-10	10	30	20	15	10	5	0	-10	-15	-20
11-15	15	25	15	10	0	-5	-10	-20	-25	-30
16-19	20	20	10	5	0	-10	-15	-25	-30	-35
20-23	25	15	10	0	-5	-15	-20	-30	-35	-45
24-28	30	10	5	0	-10	-20	-25	-30	-40	-50
29-32	35	10	5	-5	-10	-20	-30	-35	-40	-50
33-36	40	10	0	-5	-15	-20	-30	-35	-45	-55

B. Spring (March through May)

According to Brody and Nestor (1980), springtime weather in the Monaco area is characterized by periods of stormy winter-type weather alternating with false starts of more settled summer-type weather.

Easterly winds still predominate, but gradually become less strong as the season progresses, a direct result of the weakening of the low pressure systems in the Gulf of Genoa. Easterly and southerly winds which are caused by extratropical storm systems that transit the area south of Monaco may still occur, but do so with decreasing frequency after March.

Mistral events farther west generate southwesterly swell which reaches the Monaco anchorage with a height of about 6 ft (2 m). North to northwest Mistral winds occur at Monaco only during a very strong outbreak early in the season.

Precipitation occurs more frequently during spring than winter, with some form occurring on about one-third of the days during April (Biel, 1946). Mid-spring temperatures vary between 50° and 70°F (10 and 21°C) (FICEURLANT, 1983).

C. Summer (June through September)

activity is at a yearly minimum because storm track is north of the Mediterranean Basin.

According to local authorities, east to southeast winds of force 3 to 5 (7-10 kt to 17-21 kt) prevail during summer. Low pressure systems are still common in the Gulf of Genoa but are markedly weaker than those observed during winter and spring. A sea breeze occurs during the afternoon hours, but is usually weak--in the force 1 or 2 (1 to 6 kt) range. Short duration winds of 20 to 30 kt or greater are possible if the sea breeze should coincide with and reinforce an east to southeasterly gradient wind.

Precipitation is at its yearly minimum, occurring on only about 15 percent of the days during July.

D. Autumn (October)

The transition season of autumn at Monaco usually lasts for the single month of October. It is characterized by an abrupt change from the more-or-less settled conditions of summer to winter-type weather (Brody and Nestor, 1980).

The extratropical storm track returns from its summertime position in northern Europe to the Mediterranean Basin, allowing extratropical depressions to affect Monaco's weather. Cyclogenesis occurs more frequently in the Gulf of Genoa, and the resultant easterly winds at Monaco are strengthened.

Precipitation frequency and amount increases significantly from the relatively dry period of summer. Rain occurs on about 34 percent of the days of October (Biel, 1946) with the average accumulation slightly over 4 inches (10.7 cm). Temperatures decrease markedly and the wind chill factor should be considered by the end of the month.

3.6 Harbor Protection

directions, east through southeast, adversely affect the harbor. The quay along the north side of the harbor is left vacant during the winter months due to wave action. The anchorage, which is located in open sea conditions outside the inner harbor, is exposed and vulnerable to most of the hazardous conditions of the region.

3.6.1 Wind and Weather

As is the case for most ports, wind alone does not significantly affect harbor operations to any great degree. The inner harbor is afforded good protection from winds from southwest through north by the topography of the region. Most wind from those directions, except for the infrequent Mistral winds which blow from the northwest or north through the Turbie Valley to Monaco, are blocked. Winds with a strong easterly component, mainly east to southeast, cause the greatest problems at the Port of Monaco, but not because of the effects of wind alone. Instead, it is the wave energy raised by the wind which causes the difficulty. See section 3.6.2.

Other than the rain which often accompanies east to southeast winds, little inclement weather affects Monaco. Thunderstorms can be expected on about 32 days of the year at Nice, (Biel, 1946) and a like number would be expected at Monaco. Maximum occurrence is during June, with July recording only slightly fewer.

3.6.2 Waves

Because of the orientation of the landmass and the lack of fetch, waves generated by local winds from west through northeast do not cause difficulty at the Port. But wind waves which are locally generated by winds from east clockwise through southwest, and swell waves which propagate to the Monaco area from the same the main harbor at Monaco--the Port of La Condamine--allows wave energy to pass. When the waves are high enough, and waves outside the harbor entrance may reach 10 to 13 ft (3 to 4 m) when a strong low exists in the Gulf of Genoa, the inner harbor can become dangerous. The entire quay on the north side of the harbor, Quai des Etats Unis, is left vacant during winter because of the high waves. Small boat operation in the inner harbor can become extremely dangerous if not impossible.

The roadstead is afforded no protection from waves emanating from northeast clockwise through southwest. Open sea wave conditions impact the anchorage area, exposing it to easterly sea and swell of 10 to 13 ft (3 to 4 m), southerly waves to 10 ft (3 m) and southwesterly swell to 6 ft (2 m) from Mistral winds farther west.

3.7 Protective and Mitigating Measures

Since U.S. Navy ships do not routinely enter the inner harbor at Monaco, protective measures and sortie decisions are limited to those applicable to vessels anchored in the roadstead and to the small boats that make runs to/from the anchorage.

3.7.1 Moving to a New Anchorage

Because of the vulnerability of ships in the roadstead and small boats going to/from the inner harbor and anchorage, moving to a more protected anchorage should be considered during existing or forecast heavy weather conditions. The nearby Port of Villefranche affords the best protection from easterly conditions, with anchorage no. 1 at Cannes also providing protection. Most of the ports in the region are exposed and

Similarly, when southwesterly swell waves generated by Mistral winds farther west reach the French Riviera, most ports are subject to swell heights of 6 ft (2 m). But anchorage no. 3 at Cannes in Golfe Juan offers good protection in the lee of Cap de la Croisette.

3.7.2 Scheduling

The large-scale wind events which create most of the problems at Monaco are largely autumn, winter, and early spring events. Consequently, for long-range planning purposes, visits to Monaco should be scheduled for summer months whenever possible.

Considering the light sea breeze velocities and good visibilities which prevail at the Port of Monaco, there is little need to be concerned with day-to-day scheduling of routine events in Port. If minimum wind velocities are desired, an early morning evolution should be considered.

3.8 Local Indicators of Hazardous Weather Conditions

The following guidelines have been extracted from various sources and are intended to provide the insight necessary to enable the meteorologist to better understand the various phenomena that affect the Port of Monaco. Because Monaco is in an area which is not normally subjected to strong Mistral winds, most of the more technical guidelines for Mistrals have been omitted from this listing. If a more comprehensive listing is desired, the reader is referred to section 3.8 of the port studies of either Marseille or Toulon, France.

3.8.1 Easterly Winds and Waves

of Genoa. Unless otherwise specified, the following guidelines have been taken from Brody and Nestor's (1980) Regional Forecasting Aids for the Mediterranean Basin, Part 2 of the Handbook for Forecasters in the Mediterranean.

1. A lee trough is often present in the Gulf of Genoa when a cold or occluded front is moving into western France. The trough remains stationary until the arrival of the front, at which time significant cyclogenesis occurs.

2. A good indication of rapid development of a Genoa cyclone is the appearance of cold air from the northeast in the Po Valley of northern Italy. If little cold air penetrates the Po Valley from the northeast while a strong push is observed in the Gulf of Lion, cyclogenesis will probably take place in the Gulf of Venice rather than in the Gulf of Genoa.

3. Genoa lows occur almost simultaneously with the onset of the Mistral in the Gulf of Lion; conversely, these lows invariably form when conditions are right for the Mistral to occur.

4. A residual low pressure trough generally remains over the Gulf of Genoa, even after the primary low has moved well out of the region. This trough, with associated Mistral, can remain for several days.

5. Centers of Genoa cyclones are often poorly organized. Strong pressure gradients, associated with a lee trough south of the Alps, frequently are found far from the cyclones' geographic center.

6. Local authorities at Monaco state that a falling barometer is a good indication of an upcoming easterly wind.

3.8.2 Mistral

2. The Mistral will start at Marseille when one (or more) of three surface pressure differences is achieved (highest pressure to west): Perpignan - Marseille, 3 mb; Marseille - Nice, 3 mb; or Perpignan - Nice, 6 mb. A difference usually occurs from 0 to 24 hr after a closed Genoa low appears, but it occasionally occurs earlier (Brody and Nestor, 1980).

3. Eastward from Iles d'Hyères there is a rapid decrease in the frequency and in the average force of the Mistral. It blows at times all along this coast but because of its reduced frequency and intensity it is not the same threat as around the Rhône delta. The general climate of the French Riviera benefits from being sheltered from the most intense form of the Mistral which is experienced farther west (Hydrographer of the Navy, 1965).

4. The eastern boundary of the Mistral extends downwind from the western edge of the Alps through San Remo, Italy, which is about 16 n mi east of Monaco (Brody and Nestor,1980).

5. Associated weather - When fully established, the Mistral is usually accompanied by clear skies and excellent visibility (Hydrographer of the Navy, 1965). It is during the Mistral that the island of Corsica, some 95 n mi distant, can occasionally be seen from Monaco. However, rain (or in winter, rain and/or snow) and violent squalls commonly accompany the cold front which precedes the Mistral.

3.8.3 General

1. The early stages of lee cyclogenesis south of the Alps commonly result in southwesterly 30-40 kt winds in the region between the southern French coast and Corsica (Brody and Nestor, 1980).

arrive/persist after the wind changes direction, resulting in a swell direction which is at an angle of 45° to 90° to the wind. Since anchored vessels will head into the wind, the situation makes them liable to a rolling motion (Shaver, undated).

3.9 Summary of Problems, Actions, and Indicators

Table 3-2 is intended to provide easy to use seasonal references for meteorologists on ships using the Port of Monaco. Table 2-1 (section 2) summarizes Table 3-2 and is intended primarily for use by ship captains.

Table 3-2. Potential problem situations

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONAR
1. Anchored. Strongest in Winter & early Spring Weakest in Summer Also occurs in Autumn	a. E-SE'ly winds/waves - Worst weather condition at Monaco. The winds, which average force 7-9 (28-40 kt) during winter, less during summer, occur about 80% of the time at Monaco. Creates 10-13 ft (3-4 m) waves which impact the unprotected roadstead May be accompanied by rainy weather.	a. Impacts the roadstead with full o remaining at anchorage inadvisable. may be required and small boat runs t curtailed. Moving to a more protecte or anchorage no. 1 at Cannes should b chill factor.
Occurs mainly in Winter, Spring, and Autumn Uncommon in Summer	b. S-SW'ly wind/waves - Occurs infrequently. Swell seldom exceeds 6 ft (2 m), but may reach 10 ft (3 m) and persist for 2-3 days. The swell may arrive/persist after the wind changes direction, resulting in a swell direction 45°-90° to the wind direction, which causes anchored vessels to roll.	b. Impacts the roadstead with full op remaining at anchorage inadvisable. Ships may roll uncomfortably if wind a directions. Small boat runs to/from t curtailed. Moving to a more protected no. 2 north of Ile Ste. Marguerite at but most other nearby ports offer no p
Strongest in late Winter & early Spring Uncommon in Summer Also occurs in Autumn	c. Mistral wind/waves - Wind occurs as strong W to NW'ly wind farther west, but is only seen at Monaco as NW-N'ly of greatly reduced velocities. Swell generated by stronger winds west of Monaco reach the Port area with heights of about 6 ft (2 m).	c. The Mistral usually has minimal im to N Mistral wind is weaker than the o has no fetch to create a significant s generated farther west should not be a If a more protected anchorage is desir Pointe de la Croisette at Cannes shoul wind chill factor.

the tions at the Port of Monaco - ALL SEASONS

EVA	UTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
cean main m th horag sider	with full open-ocean force. May make visable. If remaining, 2 or more anchors oat runs to/from the inner harbor may be re protected anchorage such as Villefranche es should be considered. Be aware of wind	a. Because of the impact strong E-SE'ly winds/waves have on the roadstead at Monaco, it is prudent to be aware of their causes. The following guidelines address Genoa lows, the most common cause of the problem. (1) A lee trough often is present in the Gulf of Genoa when a cold or occluded front is moving into western France. The trough remains stationary until the arrival of the front, at which time significant cyclogenesis occurs. (2) A good indication of rapid development of a Genoa low is the appearance of cold air from the NE in the Po Valley. (3) Genoa lows occur almost simultaneously with the onset of the Mistral in the Gulf of Lion; conversely, these lows invariably form when conditions are right for the Mistral to occur. (4) A residual low pressure trough generally remains over the Gulf of Genoa, even after the primary low has moved well out of the region. This trough, with associated Mistral, can remain for several days. According to local authorities at Monaco, a falling barometer is a good indication of forthcoming E-SE'ly wind.
ean chor ell a ner orag s sh tion	with full open-ocean force. May make visable. Two anchors may be required. if wind and swell are from different s to/from the inner harbor may be e protected anchorage such as anchorage uerite at Cannes should be considered, s offer no protection from S'ly conditions.	b. The early stages of cyclogenesis south of the Alps commonly result in SW'ly 30-40 kt winds in the region between the southern French coast and Corsica. S'ly (160° to 220°) winds and swell can be caused by depressions moving into the Ligurian Sea or across Corsica into Italy. Swell waves seldom exceed 10 ft (3 m).
at t erie he S em chor or	s minimal impact at the roadstead. The NW than the one experienced farther west and ignificant sea. The SW swell which is uld not be a problem to ships at anchor. age is desired, anchorage no. 3 east of annes should be considered. Be aware of	c. Although the Mistral causes only minimal, infrequent problems at the anchorage, it is prudent to be aware of forthcoming Mistral events. (1) Conditions which favor the formation of a Genoa low are conducive to the start of a Mistral at Marseille. A strong Mistral at Marseille may spread east to Monaco, but will be greatly reduced in intensity. (2) The Mistral will start at Marseille when one (or more) of three pressure differences is achieved (western most point has highest pressure): Perpignan-Marseille, 3 mb; Marseille-Nice, 3 mb; or Perpignan-Nice, 6 mb. Such differences usually develops within 24 hr after a closed Genoa low appears, but it occasionally occurs earlier. (3) Going east from Iles d'Hyères there is a rapid decrease in the frequency and in the average force of the Mistral. (4) The eastern boundary of the Mistral extends downwind from the western edge of the Alps through San Remo, Italy, which is about 16 n mi east of Monaco. (5) When fully established, the Mistral is usually accompanied by clear skies and excellent visibility. However, rain (or in winter rain and/or snow) and violent squalls commonly accompany the cold front which precedes the Mistral. (6) Mistral winds will spread east to Nice and possibly to Monaco if a 10 mb pressure difference exists between Toulon and Nice.

Table 3-2.

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY
2. Moored - inner harbor. Strongest in Winter & early Spring Weakest in Summer Also occurs in Autumn	a. E-SE'ly winds/waves - Worst weather condition at Monaco. The winds, which average force 7-8 (28-40 kt) during winter, less during summer, occur about 80% of the time at Monaco. Creates 10-13 ft (3-4 m) waves which pass through harbor entrance. May be accompanied by rainy weather.	a. Waves enter Port of La Condamine an therein. The effect is so pronounced t the Port along Quai des Etats Unis is l Since U.S. Navy ships do not normally e problem is usually limited to small boat harbor, it should sortie at the first i winds/seas. The anchorage at Villefran and should be considered, with anchorag alternate. Be aware of wind chill fact
Strongest in late Winter & early Spring Uncommon in Summer Also occurs in Autumn	b. Mistral wind/waves - Wind occurs as strong W to NW'ly wind farther west, but is only seen at Monaco as NW-N'ly of greatly reduced velocities. Swell generated by stronger winds west of Monaco reach the Port area with heights of about 6 ft (2 m) but cause no particular problems in the harbor.	b. Wind and waves should not significan inner harbor, but temperature and wind f chill factor to relatively low levels. factor.

3-2. (Continued)

TIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
ondamine and create dangerous conditions ronounced that the entire north side of s Unis is left vacant during winter. normally enter the inner harbor, the o small boats. If a vessel is in the inner the first indication of strong E-SE'ly t Villefranche offers better protection th anchorage no. 1 at Cannes as an chill factor.	a. Because of the impact strong E-SE'ly winds/waves have on the roadstead at Monaco, it is prudent to be aware of their causes. The following guidelines address Genoa lows, the most common cause of the problem. (1) A lee trough often is present in the Gulf of Genoa when a cold or occluded front is moving into western France. The trough remains stationary until the arrival of the front, at which time significant cyclogenesis occurs. (2) A good indication of rapid development of a Genoa low is the appearance of cold air from the NE in the Po Valley. (3) Genoa lows occur almost simultaneously with the onset of the Mistral in the Gulf of Lion; conversely, these lows invariably form when conditions are right for the Mistral to occur. (4) A residual low pressure trough generally remains over the Gulf of Genoa, even after the primary low has moved well out of the region. This trough, with associated Mistral, can remain for several days. According to local authorities at Monaco, a falling barometer is a good indication of forthcoming E-SE'ly wind.
t significantly affect vessels in the e and wind force could reduce the wind ow levels. Be aware of wind chill	b. Although the Mistral causes only minimal, infrequent problems at the anchorage, it is prudent to be aware of forthcoming Mistral events. (1) Conditions which favor the formation of a Genoa low are conducive to the start of a Mistral at Marseille. A strong Mistral at Marseille may spread east to Monaco, but will be greatly reduced in intensity. (2) The Mistral will start at Marseille when one (or more) of three pressure differences is achieved (western most point has highest pressure): Perpignan-Marseille, 3 mb; Marseille-Nice, 3 mb; or Perpignan-Nice, 6 mb. Such differences usually develops within 24 hr after a closed Genoa low appears, but it occasionally occurs earlier. (3) Going east from Iles d'Hyères there is a rapid decrease in the frequency and in the average force of the Mistral. (4) The eastern boundary of the Mistral extends downwind from the western edge of the Alps through San Remo, Italy, which is about 16 n mi east of Monaco. (5) When fully established, the Mistral is usually accompanied by clear skies and excellent visibility. However, rain (or in winter rain and/or snow) and violent squalls commonly accompany the cold front which precedes the Mistral. (6) Mistral winds will spread east to Nice and possibly to Monaco if a 10 mb pressure difference exists between Toulon and Nice.

Table 3-2.

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTION
3. Arriving/departing. Strongest in Winter & early Spring Weakest in Summer Also occurs in Autumn	a. E-SE'ly winds/waves - Worst weather condition at Monaco. The winds, which average force 7-8 (28-40 kt) during winter, less during summer, occur about 80% of the time at Monaco. Creates 10-13 ft (3-4 m) waves which impact the unprotected roadstead and pass through harbor entrance. May be accompanied by rainy weather.	a. East to southeasterly winds and anchorage and inner harbor. Inbound protected waters, such as Villefranc to stay at Monaco during such condit factor.
Occurs mainly in Winter, Spring, and Autumn Uncommon in Summer	b. S-SW'ly wind/waves - Occurs infrequently. Swell seldom exceeds 6 ft (2 m), but may reach 10 ft (3 m) and persist for 2-3 days. The swell may arrive/persist after the wind changes direction, resulting in a swell direction 45°-90° to the wind direction, which causes anchored vessels to roll.	b. Inbound units should be aware of caused by varying wind and swell dir of small boat runs to/from the inner protected waters, such as anchorage Marguerite at Cannes should be consi
Strongest in late Winter & early Spring Uncommon in Summer Also occurs in Autumn	c. Mistral wind/waves - Wind occurs as strong W to NW'ly wind farther west, but is only seen at Monaco as NW-N'ly of greatly reduced velocities. Swell generated by stronger winds west of Monaco reach the Port area with heights of about 6 ft (2 m). Most of the impact is felt at the anchorage.	c. Inbound and outbound units shoul be stronger offshore than along the factor.

le 3-2. (Continued)

ECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
ly winds and waves pose hazards to both the bor. Inbound units should divert to more as Villefranche or Cannes rather than attempt g such conditions. Be aware of wind chill	a. Because of the impact strong E-SE'ly winds/waves have on the roadstead at Monaco, it is prudent to be aware of their causes. The following guidelines address Genoa lows, the most common cause of the problem. (1) A lee trough often is present in the Gulf of Genoa when a cold or occluded front is moving into western France. The trough remains stationary until the arrival of the front, at which time significant cyclogenesis occurs. (2) A good indication of rapid development of a Genoa low is the appearance of cold air from the NE in the Po Valley. (3) Genoa lows occur almost simultaneously with the onset of the Mistral in the Gulf of Lion; conversely, these lows invariably form when conditions are right for the Mistral to occur. (4) A residual low pressure trough generally remains over the Gulf of Genoa, even after the primary low has moved well out of the region. This trough, with associated Mistral, can remain for several days. According to local authorities at Monaco, a falling barometer is a good indication of forthcoming E-SE'ly wind.
d be aware of possible rolling at anchor nd swell directions and possible curtailment om the inner harbor. Diversion to more as anchorage no. 2 north of Ile Ste. ould be considered.	b. The early stages of cyclogenesis south of the Alps commonly result in SW'ly 30-40 kt winds in the region between the southern French coast and Corsica. S'ly (160° to 220°) winds and swell can be caused by depressions moving into the Ligurian Sea or across Corsica into Italy. Swell waves seldom exceed 10 ft (3 m).
c units should be aware of tendency of wind to an along the coast. Be aware of wind chill	c. Although the Mistral causes only minimal, infrequent problems at the anchorage, it is prudent to be aware of forthcoming Mistral events. (1) Conditions which favor the formation of a Genoa low are conducive to the start of a Mistral at Marseille. A strong Mistral at Marseille may spread east to Monaco, but will be greatly reduced in intensity. (2) The Mistral will start at Marseille when one (or more) of three pressure differences is achieved (western most point has highest pressure): Perpignan-Marseille, 3 mb; Marseille-Nice, 3 mb; or Perpignan-Nice, 6 mb. Such differences usually develops within 24 hr after a closed Genoa low appears, but it occasionally occurs earlier. (3) Going east from Iles d'Hyères there is a rapid decrease in the frequency and in the average force of the Mistral. (4) The eastern boundary of the Mistral extends downwind from the western edge of the Alps through San Remo, Italy, which is about 16 n mi east of Monaco. (5) When fully established, the Mistral is usually accompanied by clear skies and excellent visibility. However, rain (or in winter rain and/or snow) and violent squalls commonly accompany the cold front which precedes the Mistral. (6) Mistral winds will spread east to Nice and possibly to Monaco if a 10 mb pressure difference exists between Toulon and Nice.

Table 3-2.

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIO
4. Small boats. Strongest in Winter & early Spring Uncommon in Summer Also occurs in Autumn	a. E-SE'ly winds/waves - Worst weather condition at Monaco. The winds, which average force 7-8 (28-40 kt) during winter, less during summer, occur about 80% of the time at Monaco. Creates 10-13 ft (3-4 m) waves which impact the unprotected roadstead and pass through harbor entrance. May be accompanied by rainy weather.	a. During a strong event, waves out through the harbor entrance make sma not impossible. Boating should be c Be aware of wind chill factor.
Occurs mainly in Winter, Spring, and Autumn Uncommon in Summer	b. S-SW'ly wind/waves - Occurs infrequently. Swell seldom exceeds 6 ft (2 m), but may reach 10 ft (3 m) and persist for 2-3 days. The swell may arrive/persist after the wind changes direction, resulting in a swell direction 45°-90° to the wind direction.	b. Small boat operations in the inne but wind/wave conditions outside the operations to/from the roadstead unti
Strongest in late Winter & early Spring Uncommon in Summer Also occurs in Autumn	c. Mistral wind/waves - Wind occurs as strong W to NW'ly wind farther west, but is only seen at Monaco as NW-N'ly of greatly reduced velocities. Swell generated by stronger winds west of Monaco reach the Port area with heights of about 6 ft (2 m).	c. Small boat operations in the inne but wind/wave conditions outside the operations to/from the roadstead unti wind chill factor.

Table 3-2. (Continued)

PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
event, waves outside the harbor and passing entrance make small boat operation dangerous if ating should be curtailed until conditions abate. ill factor.	a. Because of the impact strong E-SE'ly winds/waves have on the roadstead at Monaco, it is prudent to be aware of their causes. The following guidelines address Genoa lows, the most common cause of the problem. (1) A lee trough often is present in the Gulf of Genoa when a cold or occluded front is moving into western France. The trough remains stationary until the arrival of the front, at which time significant cyclogenesis occurs. (2) A good indication of rapid development of a Genoa low is the appearance of cold air from the NE in the Po Valley. (3) Genoa lows occur almost simultaneously with the onset of the Mistral in the Gulf of Lion; conversely, these lows invariably form when conditions are right for the Mistral to occur. (4) A residual low pressure trough generally remains over the Gulf of Genoa, even after the primary low has moved well out of the region. This trough, with associated Mistral, can remain for several days. According to local authorities at Monaco, a falling barometer is a good indication of forthcoming E-SE'ly wind.
ions in the inner harbor are largely unaffected, ons outside the harbor may preclude small boat e roadstead until conditions abate.	b. The early stages of cyclogenesis south of the Alps commonly result in SW'ly 30-40 kt winds in the region between the southern French coast and Corsica. S'ly (160° to 220°) winds and swell can be caused by depressions moving into the Ligurian Sea or across Corsica into Italy. Swell waves seldom exceed 10 ft (3 m).
ons in the inner harbor are largely unaffected, ons outside the harbor may preclude small boat e roadstead until conditions abate. Be aware of	c. Although the Mistral causes only minimal, infrequent problems at the anchorage, it is prudent to be aware of forthcoming Mistral events. (1) Conditions which favor the formation of a Genoa low are conducive to the start of a Mistral at Marseille. A strong Mistral at Marseille may spread east to Monaco, but will be greatly reduced in intensity. (2) The Mistral will start at Marseille when one (or more) of three pressure differences is achieved (western most point has highest pressure): Perpignan-Marseille, 3 mb; Marseille-Nice, 3 mb; or Perpignan-Nice, 6 mb. Such differences usually develops within 24 hr after a closed Genoa low appears, but it occasionally occurs earlier. (3) Going east from Iles d'Hyères there is a rapid decrease in the frequency and in the average force of the Mistral. (4) The eastern boundary of the Mistral extends downwind from the western edge of the Alps through San Remo, Italy, which is about 16 n mi east of Monaco. (5) When fully established, the Mistral is usually accompanied by clear skies and excellent visibility. However, rain (or in winter rain and/or snow) and violent squalls commonly accompany the cold front which precedes the Mistral. (6) Mistral winds will spread east to Nice and possibly to Monaco if a 10 mb pressure difference exists between Toulon and Nice.

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PORT VISIT INFORMATION

JUNE 1986. NEPRF meteorologists R. Fett and R. Picard met with the Port Captain Mr. de Welles to obtain much of the information used in this port evaluation.

APPENDIX A

General Purpose Oceanographic Information

This section provides general information on wave forecasting and wave climatology as used in this study. The forecasting material is not harbor specific. The material in paragraphs A.1 and A.2 was extracted from H.O. Pub. No. 603, Practical Methods for Observing and Forecasting Ocean Waves (Pierson, Neumann, and James, 1955). The information on fully arisen wave conditions (A.3) and wave conditions within the fetch region (A.4) is based on the JONSWAP model. This model was developed from measurements of wind wave growth over the North Sea in 1973. The JONSWAP model is considered more appropriate for an enclosed sea where residual wave activity is minimal and the onset and end of locally forced wind events occur rapidly (Thornton, 1986), and where waves are fetch limited and growing (Hasselmann, et al., 1976). Enclosed sea, rapid onset/subsiding local winds, and fetch limited waves are more representative of the Mediterranean waves and winds than the conditions of the North Atlantic from which data was used for the Pierson and Moskowitz (P-M) Spectra (Neumann and Pierson 1966). The P-M model refined the original spectra of H.O. 603, which over developed wave heights.

The primary difference in the results of the JONSWAP and P-M models is that it takes the JONSWAP model longer to reach a given height or fully developed seas. In part this reflects the different starting wave conditions. Because the propagation of waves from surrounding areas into semi-enclosed seas, bays, harbors, etc. is limited, there is little residual wave action following periods of locally light/calm winds and the sea surface is nearly flat. A local wind developed wave growth is therefore slower than wave growth in the open present. This slower wave development is a built in bias in the formulation of the JONSWAP model which is based on data collected in an enclosed sea.

A.1 Definitions

Waves that are being generated by local winds are called "SEA". Waves that have traveled out of the generating area are known as "SWELL". Seas are chaotic in period, height and direction while swell approaches a simple sine wave pattern as its distance from the generating area increases. An in-between state exists for a few hundred miles outside the generating area and is a condition that reflects parts of both of the above definitions. In the Mediterranean area, because its fetches and open sea expanses are limited, SEA or IN- BETWEEN conditions will prevail. The "SIGNIFICANT WAVE HEIGHT" is defined as the average value of the heights of the one-third highest waves. PERIOD and WAVE LENGTH refer to the time between passage of, and distances between, two successive crests on the sea surface. The FREQUENCY is the reciprocal of the period (f = 1/T) therefore as the period increases the frequency decreases. Waves result from the transfer of energy from the wind to the sea surface. The area over which the wind blows is known as the FETCH, and the length of time that the wind has blown is the DURATION. The characteristics of waves (height, length, and period) depend on the duration, fetch, and velocity of the wind. There is a continuous generation of small short waves from the time the wind starts until it stops. With continual transfer of energy from the wind to the sea surface the waves grow with the older waves leading the growth and spreading the energy over a greater range of frequencies. Throughout the growth

A.2 Wave Spectrum

Wave characteristics are best described by means of their range of frequencies and directions or their spectrum and the shape of the spectrum. If the spectrum of the waves covers a wide range of frequencies and directions (known as short-crested conditions), SEA conditions prevail. If the spectrum covers a narrow range of frequencies and directions (long crested conditions), SWELL conditions prevail. The wave spectrum depends on the duration of the wind, length of the fetch, and on the wind velocity. At a given wind speed and a given state of wave development, each spectrum has a band of frequencies where most of the total energy is concentrated. As the wind speed increases the range of significant frequencies extends more and more toward lower frequencies (longer periods). The frequency of maximum energy is given in equation 1.1 where v is the wind speed in knots.

$$f_{max} = \frac{2.476}{v} \tag{1.1}$$

The wave energy, being a function of height squared, increases rapidly as the wind speed increases and the maximum energy band shifts to lower frequencies. This results in the new developing smaller waves (higher frequencies) becoming less significant in the energy spectrum as well as to the observer. As larger waves develop an observer will pay less and less attention to the small waves. At the low frequency (high period) end the energy drops off rapidly, the longest waves are relatively low and extremely flat, and therefore also masked by the high energy frequencies. The result is frequencies are considered as the "significant part of the wave spectrum". The resulting range of significant frequencies or periods are used in defining a fully arisen sea. For a fully arisen sea the approximate average period for a given wind speed can be determined from equation (1.2).

$$\bar{T} = 0.285v \tag{1.2}$$

Where v is wind speed in knots and T is period in seconds. The approximate average wave length in a fully arisen sea is given by equation (1.3).

$$\bar{L} = 3.41\ \bar{T}^2 \tag{1.3}$$

Where $\bar{L}$ is average wave length in feet and $\bar{T}$ is average period in seconds.

The approximate average wave length of a fully arisen sea can also be expressed as:

$$\bar{L} = .67\text{"L"} \tag{1.4}$$

where "L" = $5.12T^2$, the wave length for the classic sine wave.

A.3 Fully Arisen Sea Conditions

For each wind speed there are minimum fetch (n mi) and duration (hr) values required for a fully arisen sea to exist. Table A-1 lists minimum fetch and duration values for selected wind speeds, values of significant wave (average of the highest 1/3 waves) period and height, and wave length of the average wave during lower waves exist the time to fetch limited height will be shorter. Therefore the table duration time represents the maximum duration required.

Table A-1. Fully Arisen Deep Water Sea Conditions Based on the JONSWAP Model.

Wind Speed (kt)	Minimum Fetch/Duration (n mi) / (hrs)	Sig Wave (H1/3) Period/Height (sec) / (ft)	Wave Length (ft)[1,2] Developing/Fully /Arisen L X (.5) /L X (.67)
10	28 / 4	4 / 2	41 / 55
15	55 / 6	6 / 4	92 / 123
20	110 / 8	8 / 8	164 / 220
25	160 / 11	9 / 12	208 / 278
30	210 / 13	11 / 16	310 / 415
35	310 / 15	13 / 22	433 / 580
40	410 / 17	15 / 30	576 / 772

NOTES:

[1] Depths throughout fetch and travel zone must be greater than 1/2 the wave length, otherwise shoaling and refraction take place and the deep water characteristics of waves are modified.

[2] For the classic sine wave the wave length (L) equals 5.12 times the period (T) squared ($L = 5.12T^2$). As waves develop and mature to fully developed waves and then propagate out of the fetch area as swell their wave lengths approach the classic sine wave length. Therefore the wave lengths of developing waves are less than those of fully developed waves which in turn are less than the length of the resulting swell. The factor of .5 (developing) and .67 (fully developed) reflect this relationship.

A.4 Wave Conditions Within The Fetch Region

Waves produced by local winds are referred to as SEA. In harbors the local sea or wind waves may create hazardous conditions for certain operations. Generally within harbors the fetch lengths will be short and therefore the growth of local wind waves will be fetch limited. This implies that there are locally determined upper limits of wave height and period for each wind velocity. Significant changes in speed or direction will result in generation of a new wave group with a new set of height and period limits. Once a fetch limited sea reaches its upper limits no further growth will occur unless the wind speed increases.

Table A-2 provides upper limits of period and height for given wind speeds over some selected fetch lengths. The duration in hours required to reach these upper limits (assuming a start from calm and flat sea conditions) is also provided for each combination of fetch length and wind speed. Some possible uses of Table A-2 information are:

1) If the only waves in the area are locally generated wind waves, the Table can be used to forecast the upper limit of sea conditions for combinations of given wind speeds and fetch length.

2) If deep water swell is influencing the local area in addition to locally generated wind waves, then the Table can be used to determine the wind waves that will combine with the swell. Shallow water swell conditions are influenced by local bathymetry (refraction and shoaling) and will be addressed in each specific harbor study.

3) Given a wind speed over a known fetch length the maximum significant wave conditions and time needed to reach this condition can be determined.

Table A-2. Fetch Limited Wind Wave Conditions and Time Required to Reach These Limits (Based on JONSWAP Model). Enter the table with wind speed and fetch length to determine the significant wave height and period, and time duration needed for wind waves to reach these limiting factors. All of the fetch/speed combinations are fetch limited except the 100 n mi fetch and 18 kt speed.

Format: height (feet)/period (seconds)
duration required (hours)

Fetch Length (n mi) \ Wind Speed (kt)	18	24	30	36	42
10	2/3-4 1-2	3/3-4 2	3-4/4 2	4/4-5 1-2	5/5 1-2
20	3/4-5 2-3	4/4-5 3	5/5 3	6/5-6 3-4	7/5-6 3
30	3-4/5 3	5/5-6 4	6/6 3-4	7/6 3-4	8/6-7 3
40	4-5/5-6 4-5	5/6 4	6-7/6-7 4	8/7 4	9-10/7-8 3-4
100	5/6-7[1] 5-6	9/8 8	11/9 7	13/9 7	15-16/9-10 7

[1] 18 kt winds are not fetch limited over a 100 n mi fetch.

An example of expected wave conditions based on Table A-2 follows:

WIND FORECAST OR CONDITION

An offshore wind of about 24 kt with a fetch limit of 20 n mi (ship is 20 n mi from the coast) is forecast or has been occurring.

SEA FORECAST OR CONDITION

From Table A-2: If the wind condition is forecast to last, or has been occurring, for at least 3 hours:

Expect sea conditions of 4 feet at 4-5 second period to develop or exist. If the condition lasts less than 3 hours the seas will be lower. If the condition lasts beyond 3 hours the sea will not grow beyond that developed at the end of about 3 hours unless there is an increase in wind speed or a change in the direction that results in a longer fetch.

A.5 Wave Climatology

The wave climatology used in these harbor studies is based on 11 years of Mediterranean SOWM output. The MED-SOWM is discussed in Volume II of the U.S. Naval Oceanography Command Numerical Environmental Products Manual (1986). A deep water MED-SOWM grid point was selected as representative of the deep water wave conditions outside each harbor. The deep water waves were then propagated into the shallow water areas. Using linear wave theory and wave refraction computations the shallow water climatology was derived from the modified deep water wave conditions. This climatology does not include the local wind generated seas. This omission, by design, is accounted for by removing all wave data for periods less than 6 seconds in the climatology. These shorter period waves are typically dominated by locally generated wind waves.

A.6 Propagation of Deep Water Swell Into Shallow Water Areas

When deep water swell moves into shallow water the wave patterns are modified, i.e., the wave heights and directions typically change, but the wave period remains constant. Several changes may take place including shoaling as the wave feels the ocean bottom, refraction as the wave crest adjusts to the bathymetry pattern, changing so that the crest becomes more parallel to the bathymetry contours, friction with the bottom sediments, interaction with currents, and adjustments caused by water temperature gradients. In this work, only shoaling and refraction effects are considered. Consideration of the other factors are beyond the resources available for this study and, furthermore, they are considered less significant in the harbors of this study than the refraction and shoaling factors.

To determine the conditions of the deep water waves in the shallow water areas the deep water conditions were first obtained from the Navy's operational MED-SOWM wave model. The bathymetry for the harbor/area of interest was extracted from available charts and digitized for computer use. Figure A-1 is a sample plot of bathymetry as used in this project. A ray path refraction/shoaling program was run for selected combinations of deep water wave direction and period. The selection was based on the near deep water wave climatology and harbor exposure. Each study area requires a number of ray path computations. Typically there are 3 or 4 directions (at 30° increments) and 5 or 6 periods (at 2 second intervals) of concern for each area of study. This results in 15 to 24 plots per area/harbor. To reduce this to a manageable format for quick reference, specific locations within each study area were selected and the information was summarized and is presented in the specific harbor studies in tabular form.

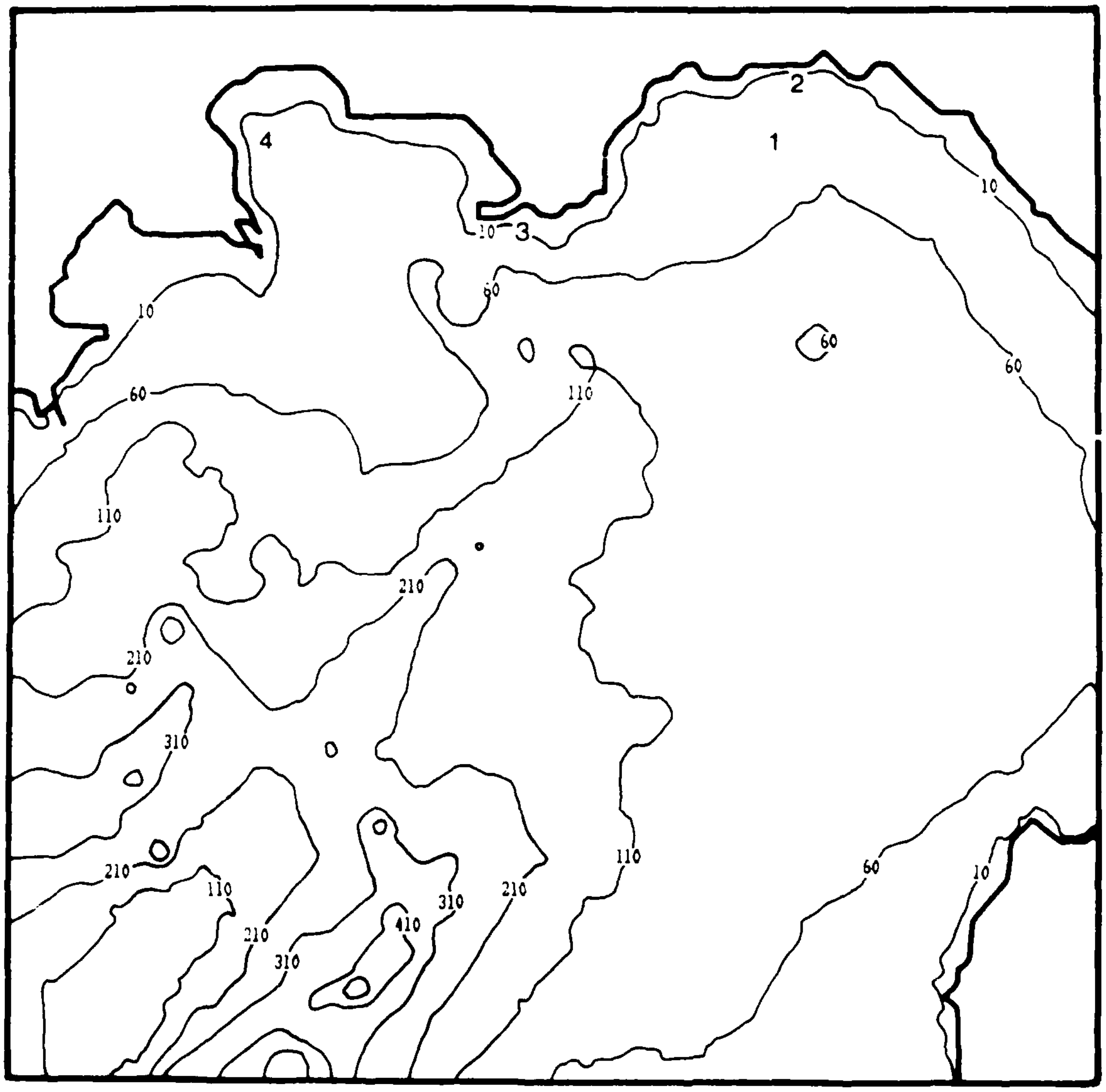

Figure A-1. Example plot of bathymetry (Naples harbor) as used in this project. For plotting purposes only, contours are at 50 fathom intervals from an initial 10 fathoms to 110 fathoms, and at 100 fathom intervals thereafter. The larger size numbers identify specific anchorage areas addressed in the harbor study.

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